Northern (2J3KL) Cod

Background

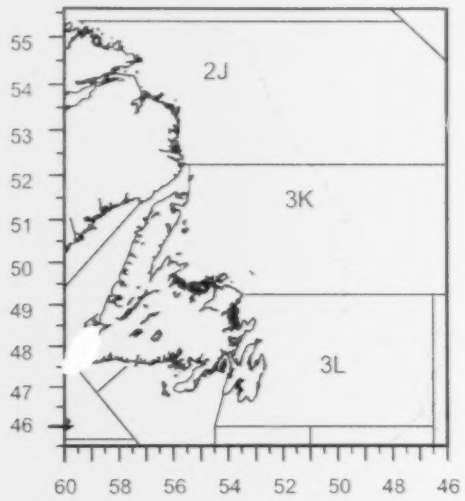
Cod has traditionally been called the "Newfoundland currency," and played a significant role in the settlement of the island. The northern (NAFO divisions 2J3KL) cod stock has been and remains potentially one of the largest in the world.

The stock covers about 117,000 square miles. Historically many cod migrated from overwintering areas offshore to feeding areas inshore. From the 1960s to the early 1990s the fishery was prosecuted with large otter trawlers offshore in the winter and spring and a large fleet of smaller vessels that deployed traps, gillnets and hook and line inshore from late spring to autumn. Some fish overwintered inshore in the past and it appears that a substantial portion of the fish currently in the stock area remain inshore throughout the year.

Cod from this stock grow more slowly than in warmer areas. An age 5 cod would be about 50 cm.(about 20 inches) long. Throughout the area female cod have a variable age at maturity, presently about age 5.

Cod in divisions 2J3KL feed on a wide variety of food items but as adults take mainly capelin.

This stock has supported a commercial fishery since the 16th century. For the century prior to 1960 the catches were mainly between 200,000 metric tons and 300,000 metric tons. With high catches in the late 1960s, mainly by foreign fleets, the stock declined until the mid 1970s. After the extension of jurisdiction in 1977, the stock increased until the mid 1980s but has declined more recently. The stock is presently at a very low level. A moratorium on fishing has been in effect since July, 1992.



The Fishery

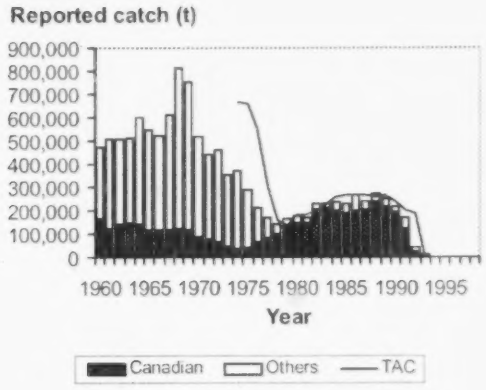
Catches by non-Canadian fleets increased rapidly in the 1960s and, although inshore landings were declining over this period, the total catch reached a peak of 800,000 metric tons in 1968. As a result of these large catches the stock declined to a low biomass by 1977.

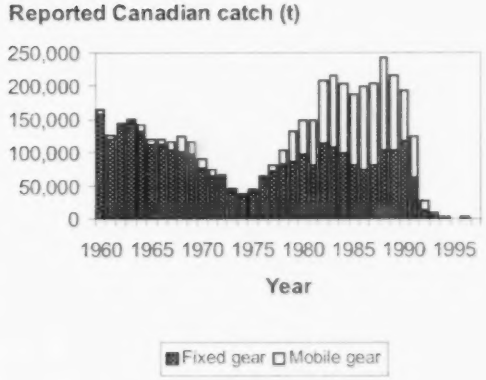
Landings (thousand metric tons)

Year	62-76 Avg.	77-91 Avg.	1993	1994[1]	1995[1]	1996[1]	1997[1]
TAC	N/A	N/A	0	0	0	0	0
Can. Fixed	88	90	9	1	+	2	1
Can. Mobile	9	84	+	0	0	+	+
Others	405	38	2	+	0	0	0
Totals	502	212	11	1	+	2	1

[1] Provisional
[+] Catch less than 500 metric tons

Canada





Following extension of jurisdiction the stock began to recover as a consequence of smaller catches, entry of the strong 1973-1975 year classes, and an increase in fish growth rate. However, the recovery of the spawner biomass stopped after about 1982 as a result of higher fishing mortality, entry of the weak 1976-1977 year-classes and a decline in growth rate. The 1978-1982 year-classes were moderate to strong but had slow growth rates. Catches during the mid- to late 1980s were relatively stable but fishing mortality was higher than thought and the stock declined through the latter half of the 1980s. The 1986-1987 year-classes appeared strong at an early age, but in concert with older year-classes appeared to decline very rapidly in the early 1990s. Fishing mortality was very high during this period but reported landings including documented discards are insufficient to account for the decline observed in the research vessel indices. A moratorium on directed commercial fishing was imposed in July 1992.

Reported catches in 1993-97 came from bycatch, food fisheries (1994 and 1996) and sentinel surveys (1995-1997). A catch of about 500 tons was reported in 1997. About 70% of this was from the sentinel survey. There is evidence of removals in excess of sentinel surveys and legal fisheries, but the magnitude of these removals cannot be estimated.

Resource Status

Stock status at the end of 1997 was updated from 1996 based on an additional year of data from commercial bycatch, the research bottom trawl surveys, inshore and offshore sentinel surveys, inshore acoustic surveys in specific bays, prerecruit surveys and a new and intensive fall acoustic survey of the inshore from White Bay to St. Mary's Bay. Additional data on the consumption of cod by harp seals up to 1995 were used.

The **fall research bottom trawl survey** index in divisions 2J3KL shows a declining trend in offshore abundance since 1995 with the 1997 value being only two thirds of that measured in 1996. Very few fish older than age 5 were encountered in 1997, and these were almost entirely in Division 3L. Total mortality rates (Z) estimated from the surveys in 1995-1997 are very high (Z = 0.77). Plausible contributors to these high mortalities include predation by seals, adverse environmental conditions and removals other than reported catches. The high estimates could also be artefacts caused

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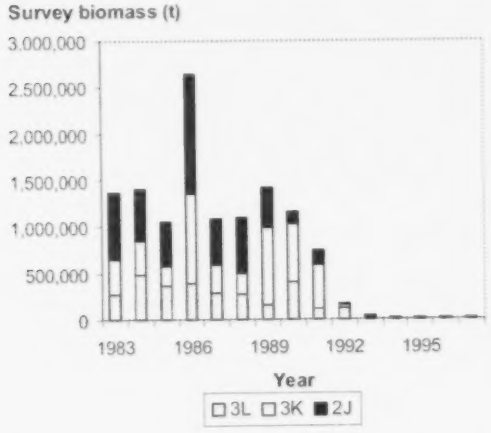
by the movement of cod to coastal waters landward of the area covered by the survey.

The biomass of cod in the offshore of 2J3KL increased a little during the 1995-1997 period as a consequence of the growth of individual fish. The minimum trawlable biomass from all strata surveyed in 1997 was estimated to be 21,000 t, which is only about 1-2% of values in the period 1983-1989.



The 1997 **spring research bottom trawl survey** in Division 3L continued to show low biomass, the minimum trawlable biomass estimate of about 7,000 t being similar to the 1993 estimate but considerably lower than the estimate in 1992.

The **offshore sentinel survey**, which was conducted with both otter trawls and gillnets in portions of divisions 3K and 3L in November and December of 1997, encountered virtually no fish with the exception of some catches from gillnets set in the vicinity of the Virgin Rocks on the plateau of Grand Bank in Division 3L.

The **inshore sentinel survey** in NAFO divisions 2J3KL, initiated in 1995 to provide indices of cod abundance in coastal waters, has been conducted primarily with gillnets and linetrawls but also with handlines and cod traps. Catch rates have been very low from White Bay north including southern Labrador. Catch rates from White Bay south are considered by participants to be good. Gillnet catch rates increased from 1995 to 1996 and remained unchanged from 1996 to 1997. Linetrawl catch rates were similar in 1995 and 1996 and increased in 1997. Handline catch rates and estimates of cod trap catches in divisions 3KL also increased in 1997 over 1995-1996. Cod caught in linetrawls in 1997 were mainly of ages 4-7 (the 1990 - 1993 year-classes) whereas those caught in gillnets were mainly of ages 5-7.

Catch rates in the inshore sentinel surveys do not provide direct measures of biomass. An attempt was made to obtain such measures by assuming that sentinel gillnet catch rates are directly proportional to cod concentration. This ratio was determined from an estimate of biomass for Placentia Bay (3Ps) in 1997 based on a mark-recapture experiment. It was then assumed that this ratio could be applied to sentinel gillnet catch rates in divisions 3KL. The biomass calculated by this method for coastal waters of divisions 3KL in 1997 was about 130,000 t. (An initial estimate of 160,000 t was based on an earlier estimate from the mark-recapture experiment. Further analysis of the data lead to this revision.)

Spring acoustic surveys in 1997 gave biomass estimates of 21,000 t for Smith Sound, 1000 t for other parts of western Trinity Bay and 1,500 t for southern Bonavista Bay. The Trinity Bay estimate can be compared to an estimate of 17,000 t from Smith Sound in 1995 and an estimate of 171 t for Smith Sound and two nearby arms in 1996.

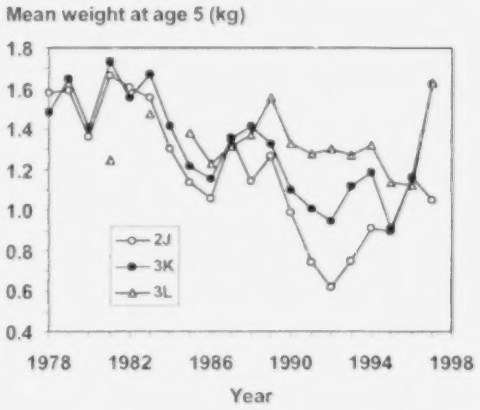
An intensive **fall acoustic survey** in 1997 covered waters landward of the research

vessel bottom-trawl survey from Cape St. Mary's at the southwestern limit of Division 3L to Great Harbour Deep in White Bay (Division 3K) in October - December. This was after the time of the traditional offshore cod migration but at the same time as the bottom-trawl survey which covered the offshore and the deeper waters of the bays. The acoustic survey gave a biomass estimate of 18,000 t, of which 80% was in Division 3L.

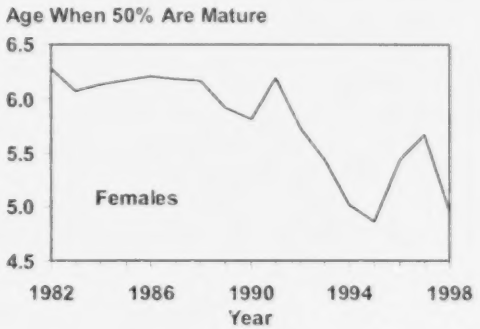
Many **fishers** felt that the biomass estimate from the inshore acoustic survey was low compared with their observations and was not compatible with the catch rates in the sentinel surveys.

Year-class strength estimated from summer **pelagic juvenile fish surveys** indicated that there has been a decline in the abundance of 0-group cod from 1994 to 1996. The 1997 estimate was between the 1995 and 1996 estimates. **Beach seine surveys** conducted in the fall from St. Mary's Bay to Notre Dame Bay obtained catch rates of demersal 0-group and 1-group cod which indicated a decline in year-class strength from 1994 to 1996 and an increase in 1997. Mean catches at age per tow during the fall research bottom-trawl surveys are in agreement with the two juvenile surveys, both of which indicated that the 1994 year-class was strong relative to adjacent year-classes. However, the bottom-trawl series shows that the 1994 year-class is weak relative to many year-classes in the 1980s. All three sources indicate that the 1996 year-class may be exceptionally weak.

Growth, measured by mean length-at-age and weight-at-age of fish sampled during the fall bottom trawl surveys, declined in the early 1990s, especially in Division 2J. Growth has increased in recent years but mean weight-at-age is still low compared with peak values in the late 1970s. Some of the variability in growth can be explained by variability in water temperature.

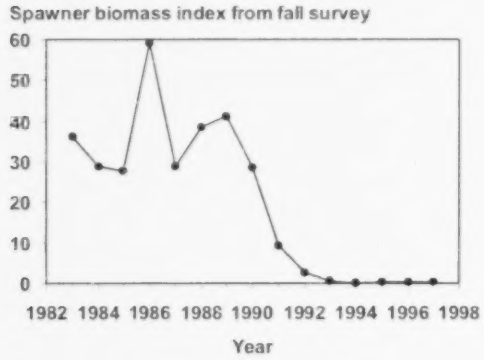


The age at which 50% of cod are **mature**, estimated from sampling during the fall research vessel surveys, declined in the early 1990s, increased from 1994 to 1996 and declined abruptly in 1997, indicating that more of the younger fish were maturing in 1997.



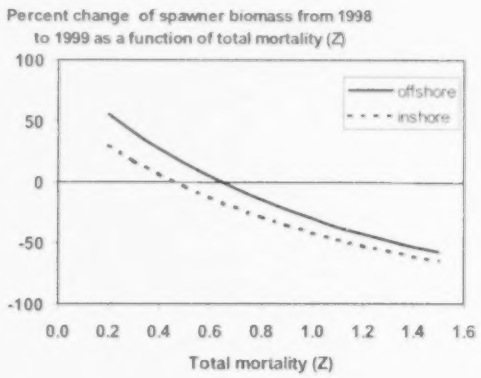
Condition factors, as measured by body weight relative to length, declined in the bottom trawl survey samples in the early 1990s in Division 2J and to a lesser extent in Division 3K. There was no apparent decline in Division 3L. Condition levels in 2J and 3K are now similar to average levels seen in the 1980s.

An index of **spawner biomass** in the offshore, calculated from annual measures of mean catch at age per tow, mean weights-at-age and the proportion mature at age, declined rapidly in the early 1990s and remains at an extremely low level.



A biologically justifiable **analytic assessment** was not achieved, even though many formulations were investigated to reconcile commercial catches and research vessel survey data. The cause or causes of the apparent rapid decline in the stock in the 1990s have not been adequately identified and measured. The current stock size is poorly measured and the risk of fishing at various levels cannot be quantified.

To explore the current **productivity** of the stock, the percentage change in spawner biomass from 1998 to 1999 was calculated for a range of values of total mortality (Z). The calculations indicate that the spawner biomass will increase only if Z is less than about 0.5 - 0.6. The current estimate of Z, based on catches in the offshore bottom trawl surveys in 1995-1997, is 0.77. It appears therefore that **the stock may decline even in the absence of any fishery**. This analysis assumes that the estimate of Z coming from the bottom trawl surveys applies to cod both offshore and inshore.



Ecological Factors

During 1995-1997 the **water temperatures** were higher than in the early 1990s when temperatures were well below average. The total volume of cold intermediate layer (CIL) water on the Newfoundland Shelf is continuing a below normal trend and ocean bottom temperatures are above normal in many locations, particularly the deeper portions of the Northeast Newfoundland Shelf. The water column temperatures at Station 27 located in the inshore branch of the Labrador Current were about normal in 1997 compared to a record high during 1996. It should be noted that mortality rates calculated from the offshore bottom trawl survey data remained high during this period of warmer water temperatures and there is no indication of improvements in recruitment.

The number of cod at various ages consumed by **harp seals** was calculated using estimates of the total amount of cod consumed, the length frequencies of cod consumed by the seals as determined from the sizes of cod otoliths found in seal stomachs, and ages at length determined from sampling during fall bottom trawl surveys. Although most of the fish taken were young (0-2 yr), substantial numbers of

older fish were also estimated to be consumed. The estimate of numbers consumed was at least 15 times higher than estimates of population numbers derived from the fall bottom trawl surveys. This very large difference could not be reconciled and it was considered that further analyses using these data could not be conducted at this time.

Major Sources of Uncertainty

There is little doubt that the cod in the offshore of divisions 2J3KL are currently characterized by small numbers and small individual size, especially in divisions 2J and 3K. Although there is uncertainty as to how a biomass estimate from a bottom trawl survey compares with the actual biomass of cod in the ocean, **the biomass estimate of 21,000 t for the offshore and deeper waters of the bays in the fall of 1997 is only 1-2% of the survey estimates in the 1980s**. The biomass estimate from the spring survey in Division 3L was also very low compared with survey estimates in the 1980s.

The fall offshore sentinel survey was new. It did not include Division 2J and had incomplete coverage in divisions 3K and 3L. Its results were not used to calculate a biomass estimate, but catches were small except in some gillnet sets around the Virgin Rocks.

Aggregations of cod have become more noticeable in inshore waters since the mid-1990s. The stock affinities of these cod are not yet clear. They may belong to some component(s) which formerly migrated between the offshore and the inshore and have remained inshore, or they may belong to inshore (coastal, bay) components. It is not known if any of these cod currently migrate seasonally between the inshore and the offshore, but the offshore bottom trawl surveys have not had one good catch of cod for four years.

The extent of along-shore migrations is also poorly known. However, with respect to the dense aggregations that have been found in Smith Sound, there is evidence that many cod overwinter and spawn in the Sound and then disperse along the coast within Trinity Bay and even into Bonavista Bay in summer and autumn, returning to the Sound the following winter. The biomass estimated within the Sound will vary depending on the time of the survey relative to the stage of the cod's seasonal migration.

The biomass of cod currently inshore remains uncertain. The fall inshore acoustic survey covered a lot of ground and located cod in many areas but only in small quantities. There is uncertainty associated with the estimate because the following three zones could not be acoustically surveyed: an area approximately 1 m above the bottom, areas of steep slope, and nearshore shallow water areas inaccessible to the survey vessels. The number of cod missed in these three zones appears to be relatively small. The number of fish that avoided the vessels because of vessel noise may be large but has not been quantified. Uncertainties associated with fish behaviour, estimation of average fish size and fish echo strength have not been quantified. Although some fishers consider that the biomass estimate of 18,000 t is low compared with their observations and could not support the catch rates experienced in the sentinel surveys, this estimate remains the only direct measure of the quantity of cod in the inshore of divisions 3KL, and should stand as an indication that the bays may not be full of cod.

Catch rates in the inshore sentinel survey may be high relative to commercial fisheries

because of the lack of competition for sites and fish. In addition, the survey does not cover the whole area formerly occupied by the stock, and therefore changes in catch rates may reflect changes in distribution of the fish rather than changes in fish abundance. Fishers themselves report that catch rates are influenced by many other factors such as weather and the availability of prey.

The 130,000 t estimate of inshore biomass is based on (i) the ratio of sentinel gillnet catch rates in Placentia Bay (3Ps) to a mark-recapture estimate of biomass in that bay and (ii) the assumption that this ratio is the same in divisions 3KL. This estimate is subject to many uncertainities, including the accuracy of the estimate of biomass in Placentia Bay and the comparability between Placentia Bay and coastal areas in divisions 3KL with respect to fishing behaviour by the sentinel fishers and the size composition of the fish. In addition, the extrapolation may be biased because of uncertainty in the relationship between gillnet catch rates and fish abundance. High catch rates can be maintained over a wide range of fish densities; ideally multiple measures of catch rate over a wide range of densities are required. The biomass derived from this procedure is much greater than the direct estimate of 18,000 t obtained from the fall acoustic survey and is perhaps more in line with what some fishers think must be there. However, it is an extrapolation that cannot be tested directly.

The conclusion that the stock may decline even in the absence of any fishery is very dependent on accurate measures of age composition, which were more uncertain for the inshore. The conclusion is based on the estimate of total mortality (Z) calculated from catches during the bottom trawl surveys and may not apply to those fish currently inshore. There is no time-series of observations from research vessel surveys that would permit calculation of Z for the inshore, but Z's calculated from catch rates at age over the short 3-year period of the linetrawl sentinel surveys in divisions 3K and 3L were much lower than the offshore values. It must be recognized, however, that the linetrawl catch rates may be influenced by many factors other than the abundance of cod and that any perception of mortality rate may change when a longer time-series is available.

The impact of seals on the 2J3KL cod stock remains unclear. Attempts at quantifying the number of young cod consumed annually by seals resulted in estimates so much higher than population estimates derived from the fall bottom trawl surveys that it was felt that further analyses could not be conducted. The large difference may arise because the surveys produce estimates which are far below the numbers actually present. The bottom trawl may have a low catchability for those cod which are within the survey area and does not encounter those cod which are in shallow coastal waters, a known nursery area. The difference between survey estimates and consumption estimates could also arise from the models and data used to calculate the numbers consumed by the seals. For example, small changes in the estimate of the proportion of cod in the average harp seal diet may result in very large differences in estimates of numbers of cod consumed when multiplied by the total consumption of the large seal population. At present the proportion of cod in the harp seal diet is based on an average for all seal stomachs examined within a given season and is assumed to be constant across years. The appropriateness of this assumption at a time when overall cod abundance has declined is questionable. Nevertheless, when the stomach data are examined on an annual

basis, there is no decline in the proportion of cod in the seal diet in recent years. Despite these reservations about the models and data used to calculate the consumption of cod by harp seals, the number of cod consumed appears to be high. In addition, the consumption of cod by hooded seals needs to be calculated and added to these estimates.

Outlook

An analytical assessment was not achieved. The risk of fishing at various catch levels cannot be quantified because the current stock size is poorly measured. It is clear however that **the overall current stock size remains very low relative to historic levels**.

Calculations based on estimates of the current total mortality from the fall bottom trawl surveys indicate that **the spawning stock could decline further even in the absence of a fishery in 1998**.

It was difficult to estimate the mortality caused by harp seals. Estimates of removals seemed much too high compared with numbers estimated from offshore bottom trawl surveys. Nevertheless, under the assumptions of the models examined it would appear that **predation by seals has been an important source of mortality of cod since the start of the moratorium**.

Based on the uncertainties about stock affinities described above, any fishery on those cod currently inshore from St. Mary's Bay in the south to White Bay in the north may hinder the ability of the cod to repopulate the offshore, especially if the cod now inshore include cod which formerly migrated between the inshore and the offshore. Cod must return in quantity to the offshore shelf from Hamilton Bank to the Grand Bank before the stock can fully utilize the resources of the area and return to its former levels of productivity. **Fishing the remaining aggregations in the inshore may retard and perhaps even prevent the recovery of the stock**.

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